Questions and Exercises

Satellite communications

1. Explain what is meant by EIRP.

The product of transmitter power and transmitter antenna gain, P_tG_t, is called the Effective Isotopically Radiated Power or EIRP. It is the power emitted by an isotropic radiator.

2. A transmitter feeds a power of 15W into an antenna which has a gain of 40dB. Calculate the EIRP in a) Watts and b) in dBW.

   a) $G_t(dB)=10\log(G_t) \Rightarrow G_t=10^{Gt/10}=10^4=10000$
   $EIRP=G_tP_t=15*10000=150$ kW

   b)
   EIRP(dBW)=Gt(db) + Pt(dB) = 40 +10log(15)=40 + 11.8=51.8dBW.

3. Calculate the gain of a 2.5m parabolic reflector antenna, having a 100% efficiency at a frequency of

   a) 6 GHz;

$$G=\frac{4\pi}{\lambda^2}A_e=\eta_e\frac{4\pi}{\lambda^2}A=1\frac{4\pi}{(c/f)^2}\frac{\pi D^2}{4}=\left(\frac{3.14\cdot 2.5}{(3\cdot 10^8/6\cdot 10^9)}\right)^2=24649 \text{ or } 43.9dB$$

   b) 14 GHz.

$$G=\left(\frac{\pi D}{(3\cdot 10^8/14\cdot 10^9)}\right)^2$$

4. The EIRP from a satellite is 50 dBW. Calculate:

   a) the power density, in dBW, at the ground station at a distance of 40 000 km.

$$P_{den}=\frac{P_tG_t}{4\pi R^2}=\frac{EIRP}{4\pi R^2}$$

$$P_{den}=EIRP-10\log(4\pi R^2)=50-10\log(4\cdot 3.14\cdot(4\cdot 10^7)^2)=50-163=-113\,dBW$$

   Be careful all distances must be in meters!

   b)the power delivered to a matched load at a ground station receiver if the antenna gain is 50 dB. The downlink frequency is 4GHz.

$$P_r = \frac{P_t G_t G_r}{(4\pi R/\lambda)^2}$$

$P_r = EIRP + G_r - 20\log(4\pi R/\lambda) = 50 + 50 - 20\log(4\pi R/\lambda)\,dBW$, λ=c/f=0.075m

5. Calculate the free space loss in dBs at a range of 42 000 km and at frequencies:

Free space loss is:

$L_p = 20\log(4\pi R/\lambda)$ [dB], λ=c/f [m], R=42*10^6 [m] replace all the values for each question.

a) 4GHz;

b) 6GHz;

c) 12 GHz;

d) 14 GHz.

6. A geostationary satellite carries a transponder with a 20W transmitter at 4GHz. The transmitter is operated at an output power of 10 W and drives an antenna with a gain of 30 dB. An earth station is at the centre of the coverage zone of the satellite at a range of 38 500 km. Using decibels for all calculations find:

a) The power density at the earth station in dBW/m^2.
G_t[dB]=30=>$G_t=10^3$

$$P_{den} = \frac{P_t G_t}{4\pi R^2} = \frac{10\cdot 10^3}{4\pi\cdot(38500\cdot 10^3)^2} =$$ $5.37\cdot 10^{-13}$ or -122.7[dBW/m^2]

b) The power received by an antenna with a gain of 39dB in dBW.

$$P_r = \frac{P_t G_t G_r}{(4\pi R/\lambda)^2}$$, λ=c/f=0.075m

$$P_r = P_t + G_t + G_r - 20\log(4\pi R/\lambda) = 10 + 30 + 36 - 20\log(4\pi\, 38500\cdot 10^3/0.075) = 79 - 196 = -120\,dBW$$

c) The EIRP of the transponder in dBW.
EIRP=10log(10)+30=40dBW

7. An LEO satellite has a multibeam antenna with a gain of 18dB in each beam. A transponder with transmitter output power of 0.5W at 2.5GHz is connected to one antenna beam. An earth station is located at the edge of the coverage zone of this beam, where the received power is 3dB below that at the centre of the beam, and at a range of 2000 km from the satellite. Using decibels for all your calculation find:

a) The power received by an antenna with a gain of 1 dB in dBW.

Pointing loss is L_{pl}=3dB, operating wavelength λ=0.12m. transmitted power P_t=10log(0.5)=-3dBW

$$P_r = P_t + G_t + G_r - 20\log(4\pi R/\lambda) - L_{pl} = -3 + 18 + 1 - 20\log(4\pi\, 2\cdot 10^6/0.12) - 3 = 16 - 166.4 - 3 = -153.4\,dBW$$

b)The noise power of the earth station receiver for a noise temperature of 260K and an RF channel bandwidth of 20kHz.

$N=kTB=1.39\cdot 10^{-23}\cdot 260\cdot 20\cdot 10^{3}=7228\cdot 10^{-20}$ W

8. A geostationary satellite carries a C-band transponder which transmits 20W into an antenna with an on-axis gain of 30dB. An earth station is in the centre of the antenna beam from the satellite, at a distance of 38 000 km. For a frequency of 4GHz find:

a) The incident power density at the earth station in dBW/m^2.

$$P_{den}=\frac{P_t G_t}{4\pi R^2}=\frac{20\cdot 10^3}{4\pi\cdot\left(38500\cdot 10^3\right)^2}=\ldots$$

$=1.07*10^{-12}$ W=-119dBW/m^2

c) The earth stations has an antenna with a circular aperture 2m in diameter and an aperture efficiency of 65%. Calculate the received power level in W and dBW at the antenna output port.

$$P_r=P_{den}A_e=P_{den}(\eta A)=P_{den}\eta\frac{\pi D^2}{4}=1.07*10^{-12}*0.65*3.14*4/4=2.18*10^{-12}W=-116.6\,dBW$$

c) Calculate the on-axis gain of the antenna in dB.

$$G=\frac{4\pi}{\lambda^2}A_e=\eta_e\frac{4\pi}{\lambda^2}A=1\frac{4\pi}{(c/f)^2}\frac{\pi D^2}{4}=\left(\frac{3.14\cdot 2}{\left(3\cdot 10^8/4\cdot 10^9\right)}\right)^2=\ldots$$

d) Calculate the free space path loss between the satellite and the earth station.

$$P_{path}=-20\log\left(4\pi R/\lambda\right)=20\log\left(4\pi\,38000\cdot 10^3/0.075\right)=196\,dBW$$

9. Two amplifiers are connected in cascade, each having a gain of 20dB and a noise temperature of 200K. Calculate:

a) the overall gain;

Gain of one antenna is $10^{20/10}=100$

Overall gain is $G_1G_2=100\cdot 100=10^4$

d) the effective noise temperature referred to input.

For the network in series effective noise temperature at the output of the network is

$$T_o=\left[G_1G_2T_1+G_2T_2\right]=G_1G_2\left[T_1+T_2/G_1\right]=G_1G_2T_e$$

Where T_e is the effective noise temperature referred to the input:

$$T_e=\left[T_1+T_2/G_1\right]=200+200/100=202\,K$$

10. Explain why is the LNA of a receiving system placed at the antenna end of the feeder cable.

To reduce the overall system temperature – see the notes

11. A 12-GHz earth station receiving system has an antenna with a noise temperature of 50K, a LNA with a noise temperature of 100K and a gain of 40dB, and a mixer with a noise temperature of 1000K. Find the system noise temperature.

G_{RF}=40 dB, T_{RF}=100K, T_a=50K, T_m=1000K; $G_{RF}=10^4$=10000

$$T_{system}=\left[T_{RF}+T_a+T_m/G_{RF}\right]=100+50+1000/10000=150.1\,K$$